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before the Subcommittee on Science, Technology and Space Committee on Commerce, Science and Transportation United States Senate

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Mr. Chairman and Members of the Subcommittee:

I am pleased to be here today to discuss NASA's efforts to better understand planet Earth and to provide you with a sense of how the program will generate solid science results and benefits to all Americans - both today and in the future. Mission to Planet Earth is one of the most important efforts underway in NASA today and is a critical part of the global effort to unlock the secrets of the environment.

A New Perspective on the Earth

When the astronauts first looked back on the Earth during their trip to the Moon, they saw a small, blue "marble" framed against a sea of dark, empty space. That picture changed the way we think about the Earth. NASA's missions to other planets have found them to be fascinating and diverse, but lifeless and sterile. We know of no place like the Earth.

What the astronauts observed was a planet in a constant state of change. We understand some of these changes pretty well - short term weather forecasts, hurricane tracking, and the way things grow. But we are missing a lot of other critical information, like the kind of data we need to predict how the climate will shift a year from now, and what the effects will be on people whose livelihoods depend on that climate - farmers, water managers, fishermen.

As we have come to recognize the economic, social, and scientific need to better understand how the Earth works, the U.S. has become a leader in organizing the global effort to observe the global environment and its effects on human quality of life. NASA has developed a program - Mission to Planet Earth - that captures our spirit of exploration and focuses it back on the Earth. Building on our observations of the Earth since the dawn of the space program - among other things, we built the first weather satellites - NASA is using its unique capabilities to bring congruency to a disconnected series of individual observations and to provide a global perspective of our land, air, water, and life. Mission to Planet Earth is an essential part of the US Global Change Research Program - a national program consisting of many federal agencies which is committed to studying climate change on a global scale.

Mission to Planet Earth has been challenged to answer the timely questions about our planet that have been raised to a high level of consciousness in recent years. As we begin to form and validate viable theories about the Earth, NASA has answered the call to provide a service no other agency can offer: cutting-edge observations from space. Instead of being captive to whatever climate changes may occur over time, NASA and its interagency and international partners are striving to discover patterns in climate that will allow us to predict and perhaps respond to environmental events - such as floods and severe winters - well in advance of their occurrence. Nations, regions, and individuals can then use this knowledge to prepare for these events, likely saving countless lives and resources.

We need to begin these valuable measurements now. For example, these observations and analyses will lead to the development of long term weather prediction, which will greatly improve both our daily lives and longer term planning. Farmers can begin to better manage what has been the greatest risk factor in their business: the uncertainty of climate patterns. Losses of crops and livestock previously caused by shifts in seasonal weather patterns or by adverse weather conditions could be reduced by altering crop/livestock selection, exploring innovative farming techniques, or perhaps not planting certain crops during a particular season. Market forces might allow farmers in regions not under threat to increase their productive capabilities to prevent shortages.

Uncertainty affects the nations of the world in different ways. African nations are often concerned with severe droughts while those in Southeast Asia may desire to know with more precision when a monsoon may hit their shores. The U.S. is concerned with the likelihood of floods along the Mississippi, rainfall patterns over agricultural areas, and damaging storms along our heavily populated coastlines. Since the entire Earth is affected by climate changes, Mission to Planet Earth is an international program which will enable regional forecasts to identify potential trouble spots around the globe in the future.

Science is the foundation of Mission to Planet Earth

While the beneficiaries of Mission to Planet Earth are many and range from farmers to the insurance industry, the program is grounded in solid science. Advanced scientific endeavors are not new to NASA: we were pioneers in developing the weather, communications, and land-sensing satellites that produce data and images which are now a part of our daily lives. We learned that we must have good science before these practical benefits are possible.

NASA's Mission to Planet Earth program is designed to address a fundamental scientific challenge: how do the Earth's land, water, air, and life all interact to produce the environment in which we live? Scientists believe that understanding how each of these parts of the Earth are linked to each other is the key that will help provide the "user's guide" for our planet. The potential human benefits of this understanding are broad and substantial.

To do this complex job, one must go beyond the traditional approach to studying the Earth (i.e., looking at each individual part) and establish one that focused on the "big picture." NASA's program expands the conventional, departmentalized scientific approach to encompass the Earth as a unified system: interdisciplinary scientists from Maine to Hawaii and from the High Plains to Texas - and from the US to more than a dozen other nations - are joined together through a unique information system to explore the complex interrelationships of Earth's land, air, water, and life. Though ground and aircraft measurements certainly play an important role for these pioneering scientists, only space can provide the economical means for providing these observations on a global scale.

The scientific community spelled out the critical pieces of the puzzle that we need to have in order to gain the understanding we seek. They laid out the most fundamental questions which need to be answered and described the observations needed to answer them. Over the course of the last three Administrations, NASA and its partners in the U.S. Government and around the world responded to this challenge by developing complementary and interconnected observation, data, and research systems designed to provide the most cost-effective means of acquiring and analyzing the highest-priority measurements. The resulting science will provide US leadership in the development of an international consensus on the state of the Earth today and in the future. We are confident that we have developed a balanced approach that will yield not only long term predictions of climate change, but will also provide short term information which will benefit states and localities, educational institutions, the business community, and the public at large.

A Science-Driven Program

The primary method for making these important measurements are space-borne satellites: they provide the global perspective and precision we must have to discern the intricate interactions of our land, air, water, and life. How much carbon dioxide seeps down into the ocean? How does the movement of warm water in the Pacific influence flooding along the Mississippi River? How do increases in human population affect our climate? Though some of these questions may seem esoteric, the answers to many of them will be the foundation from which practical benefits will flow.

The perspective from space is critical. Only from above can we observe places where it is impossible (or very difficult) to make ground observations - like distant parts of the world's oceans, deserts, and polar regions. Space observations enable us to measure the globe on a regular basis and to do so far more cost effectively than would be possible from the ground. Using this "big picture," scientists can then build computer models that simulate how the Earth behaves. More importantly, they can use this global understanding to focus on what people really care about: what is happening in their state or region. In essence, the global nature of the science in Mission to Planet Earth is actually what will enable most of the practical benefits closer to home.

A quick example of the need for global observations is El Niño. Occurring on a fairly regular basis for hundreds of years, El Niño is a climate disturbance caused by the eastward movement of warm water across the Pacific. When the water reaches the coast of the Americas, it totally jumbles the climate patterns in North and South America. This year's heavy rains in California and the 1993 Mississippi floods are thought by many scientists to be among examples of the El Niño's effect. As far away as Austrailia and Africa, the same El Niño effect can cause drought. Only with global measurements from space can scientists track and begin to predict the movement of the El Niño and monitor its many effects. As measurements improve over the coming years, researchers will be able to predict these events - and their consequences - more than a year in advance, giving farmers, landowners, and others a chance to plan accordingly and perhaps avoid devastating losses. We could make advance preparation for floods, advise farmers to customize their crops for the anticipated weather patterns, and encourage property owners to avoid building in particular regions. If a region is projected to be abnormally cold and wet, utility companies could plan to have excess capacity and local governments could prepare for excessive snowfall.

The uncertainty of our climate patterns is one of the many unanswered questions about the Earth; NASA has already begun to answer some of them. NASA launched the UARS satellite to study the atmosphere and joined with the Russians on TOMS METEOR to explore ozone depletion. More recently NASA collaborated with France to send the TOPEX/Poseidon spacecraft into orbit,

which will precisely determine sea level height and track El Niño events. We continue to provide NOAA with state-of-the-art weather satellites that improve our predictive abilities.

In the next few years, NASA will continue to expand our knowledge of the Earth. This year a private company will launch SeaStar, a spacecraft designed to provide NASA will scientific data on life in the oceans--data which may also be marketable to the fishing, oil, and shipping industries. Next year, NASA has planned Lewis & Clark, two collaborative missions with private industry which will provide scientists, businesses, and governments with extremely detailed images of the land. The Lewis mission is an example of a process in which NASA develops the technology enabling the private sector to create new markets: it will use 384 color bands (compared to 7 on Landsat) for close-up land images. In 1997, we will join with the Japanese on the TRMM mission to study tropical rainfall, which is an essential element in the climate change equation.

Landsat: A Proven Record of Accomplishment

In late 1998, we will launch Landsat-7, to continue one of the most important environmental monitoring and research tools we have. The continuation of the Landsat series of measurements is a crucial component of the comprehensive Earth Observing System (EOS) series, focusing on land studies. The Landsat series began in the early 1970's, and has provided the scientific community with a wealth of information on most of the Earth's land surface. Landsat data is stored at the EROS Data Center in South Dakota, which has played a critical role in making the benefits of Landsat widely available. It will continue in this essential role as the Distributed Active Archive Center which houses <u>all</u> of the land data from our missions.

While originally developed as a scientific tool, Landsat has evolved into a practical resource for land managers, farmers, educators, and state and local planners. Once creative users learned what Landsat could provide, they developed ways of translating the data into useful products. Some examples demonstrate Landsat's broad utility:

- o The wine industry can use the data to assess insect infestations in their vineyards
- o Local governments use the data to predict fire hazardous areas
- o Insurance companies use it to assess damage in flood ravaged regions
- o States use the data to study local ecosystems, such as the loss of critical marshland which affects fishing and wildlife
- o USDA is using the data to measure crop residue which prevents wind and rain erosion

The Best is Yet to Come: The Earth Observing System (EOS)

The key to understanding the integrated Earth system is the Earth Observing System (EOS), scheduled for first launch in 1998. Using a series of different satellites, EOS will look at the Earth in a totally new way: rather than focusing on just one aspect (land or ocean or air), EOS satellites will carry instruments designed to observe multiple aspects of the planet. By getting this kind of information, scientists will be able to see the interactions and enable to move beyond a description of "what" is happening to an understanding of "why."

EOS is the first comprehensive system designed specifically to study the Earth as a complex series of interactions between life, air, water, and land. EOS is composed of 24 essential measurement areas which a consensus of scientists believe will answer the complex questions of climate change. Over a 15-18 year period, EOS satellites will fly in over most of the Earth's surface, gathering data such as global changes in the atmosphere, land surface, pollution, and water resources. What were once studied as isolated events will be examined as interconnected and interactive forces which form a comprehensive snapshot of the Earth as a whole.

As in the case of Landsat, the science data from EOS will generate information that will benefit people's lives and livelihoods and certainly provide the opportunity for the commercial sector to develop enhanced data products. Each EOS satellite will provide science information on distinct aspects of the land, atmosphere, water and life that will touch different segments of society - the global understanding will yield local and regional benefits. A sampling of those we can predict with confidence includes:

- Error! Bookmark not defined. EOS-AM broadens the scope of Landsat to begin to predict climate change. Its satellite data will provide valuable land images for farmers, businesses, state/local governments
- Error! Bookmark not defined. EOS-PM measurements will enable fundamental improvements in climate and weather forecasting, thus giving farmers and others a powerful tool for managing what they plant and when
- Error! Bookmark not defined. EOS-CHEMISTRY observations will greatly improve monitoring of air pollution and ozone levels
- Error! Bookmark not defined. EOS-ALTIMETRY (RADAR) data will enable us to make precise sea level measurements and determine whether ocean levels are rising, a subject of considerable interest to the 50% of the U.S. population living within 50 miles of a coastline. This mission will also help track and forecast El Niño events
- Error! Bookmark not defined. EOS-ALTIMETRY (LASER) readings will accurately measure polar ice sheets and their effect on global climate and sea levels

Of course, neither NASA nor the business community can predict the ultimate marketability of this data with any certainty. But given the types of measurements planned, the positive lessons from Landsat, and the increasing sophistication of the user community, it takes little imagination to think that the science data and understanding we produce today and tomorrow will enable the private sector to develop myriad marketable data products (some of which we can't even project today). Mission to Planet Earth is part of greater research and development investment which is needed by the US to remain competitive in world markets.

And Mission to Planet Earth goes beyond commercial marketability: these scientific endeavors will enable us to begin to answer fundamental, long term questions about the Earth. The ability to forecast climate one or more years in advance will be our most critical capability. Many other important questions are also answered in this quest to forecast climate. Is the sea level consistently rising over time? How do the activities of humans influence the Earth? Can we maintain the progress we have made in protecting the Earth's vital ozone layer? How will the long term climate change? As we piece the puzzle together, answers to these questions will become clearer and we will enhance the quality of life for ourselves and succeeding generations.

Getting information to people is the key

In this age of information, a state-of-the-art, evolving system to provide data is essential. Mission to Planet Earth has designed the Earth Observing System Data and Information System (known as "EOSDIS") to relay large amounts of information to scientists, educators, governments, businesses, and the general public. Through a series of nine Distributed Active Archive Centers, any data set can be accessed (via the Internet and other means) by thousands of users at the same time throughout the world. As the amount of data and the number of people using the system increases, the system is designed to take advantage of advances in technology to provide timely and comprehensive information.

We need the expertise of people across the world if we are to derive optimal benefit from climate change research. To assist in accomplishing this goal, the EOSDIS is designed to provide our information at the lowest possible cost (the marginal cost of reproduction) to anyone, anywhere on Earth. The more diverse the group of people working on a project, the greater the opportunity for discovery. And the data system may also influence behavior around the world. For example, a Swedish scientist writing a paper on deforestation in Germany may influence a Chinese forestry official to take steps to prevent repeating a harmful situation in his own country.

This low cost data will also be available to the value-added industry. The raw data is enhanced by this industry to provide benefits that reach beyond the scientific community. A local government could develop valuable data to

benefit their community or a corporation could target the data for a specific market niche. For example, surburban planners around Seattle could use raw Landsat data to plan the growth of their community into the 21st century. Close-up land images from the Lewis mission (planned for launch next year) and others will eventually help farmers decide the precise amounts of fertilizer to use on their crops. The future uses of this data will be limited only by our imagination.

Just like the Earth, Mission to Planet Earth is ever changing

NASA is always on the forefront of new technology and approaches, and the Mission to Planet Earth program is no exception. While the science foundation of the program - and the fundamental questions it is designed to answer - have not changed, we are constantly examining ways we could improve program implementation. Since the program was approved in 1990, we have reduced the near-term cost (through 2000) of the Earth Observing System by 60% while maintaining the highest priority measurments. We are also looking at ways that we could incorporate evolving technology into the program more readily in the future. NASA is currently conducting studies to examine these questions, as well examining a closer synergy between our activities and those of the National Oceanic and Atmospheric Administration (NOAA). We will be reviewing the results of these studies with the National Academy of Sciences in July. Preliminary analyses by NASA indicate that technological advances and operational efficiences should allow us to reduce the cost of the long term program by 30% (beginning in 2001 and running through the end of the program). While cost savings are essential, we are also committed to continually evolving Mission to Planet Earth into a premier 21st century scientific enterprise.

Moving Forward

The President's FY 1996 budget enables us to move forward with the implementation of this important program (see appendix). From a scientific and practical basis, we urgently need to know the answers to these fundamental questions of climate change. We have, in concert with our numerous domestic and international partners, designed a system of observation and analysis to meet this challenge. We know that, because it is rooted in solid science, this system will provide us with a wealth of near-term benefits and answers to fundamental, long-term climate questions.

Once before, NASA missions and people helped change the way we think about the Earth. Over time, we are confident that the data and information from Mission to Planet Earth will help us and our children think clearly about the world we all live on.